Review Article

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NANODENTISTRY – A DENTAL BOON

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ABSTRACT

Nanotechnological advances should be viewed in the context of other expected developments relevant to oral health in the coming decades. Biological approaches such as tissue and genetic engineering will yield new diagnostic and therapeutic approaches much sooner than will nanotechnology. At the same time continual refinement of traditional methods, development of advanced restorative material and new medications and pharmacological approaches will continue to improve dental care. Trends in oral health and disease also may change the focus on specific diagnostic and treatment modalities. Deeper understanding of the causes and pathogenesis of other disease processes such as periodontal disease, developmental craniofacial defects malignant neoplasm should make prevention a viable approach. The role of the dentist will continue to evolve along the lines of currently visible trends. The best technical abilities, professional judgment and strong interpersonal skills are the hallmark of the contemporary dentist. Eventhough research work and clinical trials on nanorobots are in the early stage, researchers are quite optimistic regarding the use these microrobots in dentistry.

KEYWORDS: Nanomedicine; nanodentistry; nanotechnology; nanorobots

INTRODUCTION

Science is undergoing yet another change, in helping mankind enter a new era, the era of nanotechnology. "Nano" is derived from the Greek word for 'dwarf. Nanotechnology is the science of manipulating matter measured in the billionths of meters or manometer, roughly the size of 2 or 3 atoms.[1]

HISTORY

There is much controversy regarding the history of nanotechnology. Although some researchers believe that it is a scientific evolutionary form that did not develop until the late 1980s, evidence of nanotechnology dates back to 1959. Others believe that humans have unwittingly employed nanotechnological methods for thousands of years, perhaps even longer. One of the first mentions of the distinguishing concepts in nanotechnology (but predating the use of that name) was in 1867. At that time, James Clerk Maxwell proposed, as a thought experiment, a tiny entity known as Maxwell's Demon that was able to handle individual molecules.[2] The late Nobel prize winning physicist Richard P. Feynman speculated the potential of nanosize devices as early as 1959 and in his historic lecture in 1959, he concluded saying, "this is a development which I think cannot be avoided." Forty years ago, this talk was greeted with astonishment and skepticism. However, since then, there has been a remarkable progress toward realizing Feynman's vision.[3] Nano in Greek means "dwarf," and the term "nanotechnology" was coined by a student at the Tokyo Science University in 1974.[4] Growing interest in the future medical applications of nanotechnology is leading to the emergence of a new field called "Nanomedicine", where it is defined as the science and technology of diagnosing, treating, and preventing disease and traumatic injury, relieving pain, and preserving and improving human health, with the help of nanotechnology.[5]

Similarly, development of “nanodentistry” will make possible the maintenance of near-perfect oral health through the use of nanomaterials,[6,7] biotechnology[7-11] including tissue engineering, and nanorobotics.[12,13]

APPLICATIONS OF NANOROBOTICS TO DENTISTRY

Feynman has described how medical nanorobots might use specific motility mechanisms to crawl or swim through human tissues with navigational recession; acquired energy, and sense and manipulate their surroundings; achieve safe cytopenetration (for example - pass through plasma membranes such as the odontoblastic process without disrupting the cell, while maintaining clinical biocompatibility) and use any of a multitude of techniques to monitor, interrupt or alter nerve impulse traffic in individual nerve cells.[14] Nanorobots in dentistry have a potential to show its effectiveness in inducing oral analgesia, desensitizing tooth, and manipulating the tissue to re-align and straighten irregular set of teeth and improving durability of teeth. However these devices are in the development phase and only hypothetical nanorobot has been produced.[15]

Mechanism of action of Nanorobots

The powering of nanorobots is expected to be done by metabolism of local glucose, oxygen and externally supplied acoustic energy. Its functions may be controlled by an on-board nanocomputer that executes preprogrammed instructions in response to total local robots via acoustic signals (as are used in ultrasonography) or other means similar to an admiral commanding a fleet and Communication with the device can be obtained by acoustic signaling navigational network installed in the body that would provide high positional accuracy to all passing nanorobots and help in keeping track of various devices in the body. When the task of the nanorobots is completed, they can be retrieved by allowing them to effuse themselves via the usual human excretory channels. These can also be removed by active scavenger systems.[16]

APPLICATION OF NANOTECHNOLOGY IN DIAGNOSIS AND TREATMENT

Nanodiagnostics

Nanomedicine could increase the efficiency and reliability of in vitro diagnostics, through the use of selective nanodevices to collect human fluids or tissue samples and to make multiple analyses at the subcellular level. From an in vivo perspective, nanodevices might be inserted into the body to identify the early presence of a disease, or to identify and quantify toxic molecules, tumor cells, and so forth.[17,18]

Diagnosis of oral cancer

Saliva is used as an inexpensive and noninvasively obtained diagnostic medium that contains proteomic and genomic markers for molecular disease identification. Exosome, a membrane-bound secretory vesicle, is one such marker whose level is elevated in malignancy. This marker has been studied by using atomic force microscopy, which employs nanoparticles. The nano electromechanical system, oral fluid nanosensor test, and optical nanobiosensor can also be used for diagnosing oral cancer.[19,20]

a) Nano Electromechanical Systems (NEMS)

Nanotechnology based NEMS biosensors that exhibit exquisite sensitivity and specificity for detection of abnormal cells at molecular level are being developed. They convert (bio) chemical to electrical signal.[32]

b) Oral Fluid NanoSensor Test (OFNASET)

The Oral Fluid NanoSensor Test (OFNASET) technology is used for multiplex detection of salivary biomarkers for oral cancer.[33]

c) Optical Nanobiosensor

The nanobiosensor is a unique fiberoptics-based tool which allows the minimally invasive analysis of intracellular components (Cytochrome C).[19]

NANOROBOTS IN CLINICAL DENTISTRY

To Induce local anesthesia

By applying a colloidal suspensions containing millions of active, analgesic, micron-sized dental robots that respond to input supplied by the dentist are applied on the crown or mucosa which can reach the pulp via the gingival sulcus, lamina propria, or dentinal tubules.This will result in the target tooth instantly becoming completely numb by establishing control over nerve-impulse traffic. When treatment is over, a second signal causes all sensation to return to normal. providing the patient with anxiety-free and needleless comfort. The advantages includes it is fast, reversible and not associated with any side effects or complications.[17,18]

Nonsurgical Devices and Naneedles

A surgical knife has been designed from micro structured-silicon (non-magnetic and biocompatible) with a diamond-layered tip (chemically rigid). Nanosized stainless-steel crystals incorporated into suture needles have been developed with an advantages of giving sharper incisions and lower penetration pressure. Cell surgery may be possible in the near future with nanotweezers, which are now under development.[21]

Nanorobotic Dentifrice [dentifrobots]

Subocclusal dwelling nanorobotic dentifrice delivered by mouthwash or toothpaste could patrol all supragingival and subgingival surfaces atleast once a day, metabolising trapped organic matter into harmless and odorless vapors and performing continuous calculus debridement. These invisibly small dentifrobots [1-10 micon], crawling at 1-10 microns/sec, would be inexpensive, purely mechanical devices, that would safely deactivate themselves if swallowed and would be programmed with strict occlusal avoidance protocol.[22]

Dental Hypersensitivity

Dental hypersensitivity is another pathological phenomenon that may be amenable to nanodental treatment. It may be caused by changes in pressure transmitted hydrodynamically to the pulp. This is based on the fact that hypersensitive teeth have 8 times higher surface density of dentinal tubules and tubules with diameters twice as large than nonsensitive teeth. Dental nanorobots could selectively and precisely occlude selected tubules in minutes, using native biological materials, offering patients a quick and permanent cure.[23-25]

Nanocomposites

Tooth durability and appearance may be improved by replacing upper enamel layers with pure sapphire and diamond which can be made more fracture resistant as part of a nanostructured composites material that possibly including embedded carbon nanotubes.[21] Microfillers in composites and microcore materials have long been in use and nanocomposite particles are minute enough to be synthesized at the molecular level and improve the compressive strength of the material. Zirconium dioxide used as filler of submicron size, are necessary to improve polishability and esthetics. However, when particles of this size are used, the material may be more prone to brittleness and cracking or fracturing after curing. To address this issue, hybrid composites and composites containing a wider distribution of filler particles have come into use. Additionally, the even distribution of nanoparticles results in a smoother, creamier consistency and improves flow characteristics. Once the material is cured to its hardened state, these properties contribute to the dentin-like cutability and polishability of the material.[26]

Nanosolutions

Because they produce unique and dispersible nanoparticles, nanosolutions can be used as bonding agents. Homogeneity is ensured, because the adhesive is mixed perfectly every time. Nanoparticles have also been used as sterilizing solutions in the form of nanosized emulsified oil droplets that bombard pathogens.[17]

Renaturalization Procedures

Dentition renaturalization procedures may become a popular addition to the typical dental practice providing perfect treatment methods for esthetic dentistry. There would be demand for full coronal renaturalization procedures with the affected teeth remanufactured to beome indistinguishable from the original teeth.[5]

Tooth repositioning

Orthodontic nanorobots could directly manipulate the periodontal tissues including gingivae, periodontal ligament, cementum and alveolar bone allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours. A new stainless-steel wire that uses nanotechnology is being studied that combines ultra-high strength with good deformability, corrosion resistance, and surface finish in contrast to current molar up righting techniques, which require weeks or months to complete.[27]

Impression materials

Nanofillers are integrated into vinylpolysiloxanes, producing a unique siloxane impression material that has a better flow, improved hydrophilic properties, and enhanced precision detail.[26]

Dental implants: structure, chemistry, and biocompatibility

Bone is a natural nanostructure that is composed of organic compounds (mainly collagen) and reinforced with inorganic ones. Nanotechnology aims to emulate this natural structure for orthopedic and dental applications and, more particularly, for the development of nanobone. The determining factors for successful osseointegration are surface contact area and surface topography. However, bone bonding and stability also play a role. Bone growth and increased predictability can be effectively expedited with implants by using nanotechnology. The addition of nanoscale deposits of hydroxyapatite and calcium phosphate creates a more complex implant surface for osteoblast formation. Extensive research on the effects and subsequent optimization of microtopography and surface chemistry has produced ground-breaking strides in material engineering. These new implants are more acceptable, because they enhance the integration of nanocoatings resembling biological materials to the tissues.[30,31]

Nanoencapsulation

Trials on controlled drug release has been best experimented in Nano materials with hollo spheres, nanotubes, core-shell structure and nanocomposite.[8,9] Target delivery system has been developed successfully by SWRI [South West Research Institute] that involves nanocapsules including antibiotics ,vaccines and drug delivery. Targeted release systems that encompass nanocapsules are under trial for inclusion in vaccines and antibiotics.[28,29]

Treatment of Oral Cancer

Nanoshells, which are miniscule beads, are specific tools in cancer therapeutics. Nanoshells have an outer metallic layer that selectively destroys cancer cells, while leaving normal cells intact. Brachytherapy is an advanced form of cancer treatment. Still under trial are nanoparticle-coated, radioactive sources placed close to or within the tumor to destroy it. Other uses of nanovectors include drug delivery across the blood–brain barrier in the treatment of Alzheimer's and Parkinson's diseases.[19,20]

Photosensitizers and Carriers

Quantum dots can be used as photosensitizers and carriers. They can bind to the antibody present on the surface of the target cell and when stimulated by UV light, they can give rise to reactive oxygen species and thus will be lethal to the target cell.[26]

Major Tooth Repair

Nanodental techniques for major tooth repair may evolve through several stages of technological development, first using genetic engineering, tissue engineering and regeneration, and later involving the growth of whole new teeth in-vitro and their installation. Complete dentition replacement was the basis for research by Chan et al., who recreated dental enamel, the hardest tissue in the human body, by using highly organized microarchitectural units of nanorods.[21]

CONCLUSION

Nanodentistry still faces many significant challenges in realizing its tremendous potential. Basic engineering problems from precise positioning and assembly of molecular scale parts to economical mass production techniques, to biocompatibility and the simultaneous coordination of the activities of large number of independent micrometer scale robots. In addition, there are larger social issues of public acceptance, ethics, regulations and human safety that must be addressed before molecular nanotechnology can enter the modern medical armamentarium. However, there is equally powerful motivation to surmount these various challenges such as the possibility of providing high quality dental care to 80% of the world's population that currently receives no significant dental care. Time, specific advances, financial and scientific resources and human needs will determine which of the applications to be realized first. However, researchers have predicted that high-tech and effective management at the microscopic level, termed nanotechnology, will become an important part of future dental and periodontal health.

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